Real-Time Observations Of A Coastal Upwelling Event Using Innovative Technologies

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LONG-TERM GOALS

Our long-term objective is to contribute to the development of the components of limited area, open-boundary, coastal nowcast/forecast systems that will resolve the time and length scales of the relevant ocean dynamics in shallow coastal environments.

OBJECTIVES

Our specific objectives for this year were: 1) to determine if a short-term forecast (2-3 days) of the bioluminescence potential is possible with the modeling of bioluminescence intensity by tracers; 2) to develop HF radar (CODAR) derived surface currents data assimilation techniques.

APPROACH

Bioluminescence potential (BL) predictability experiments (predictions of intensity, depth and distance offshore of the BL maximum) were conducted by using tracers dynamics with velocities and diffusivities from the fine-resolution model of the Monterey Bay Area (ICON model, developed in "An Innovative Coastal-Ocean Observing Network (ICON)" project sponsored by the National Oceanographic Partnership Program, Shulman et al., 2000, Shulman et al., 2000, http://www.coam.usm.edu/ICON) and from a finer-resolution submodel of the ICON model (frsICON, around the upwelling front at the north of the Monterey Bay, http://www.coam.usm.edu/ICON).

For tracer initialization, observations are assimilated into the tracer model while velocities and diffusivities are taken from the hydrodynamic model and kept unchanged during initialization. This dynamic initialization procedure provides the initial tracer distribution that is balanced with the velocity and diffusivities fields from the hydrodynamic model. After that, three days of prognostic calculations were conducted.

Assimilation of CODAR-derived surface currents is based on application of the Physical-space Statistical Analysis System (Cohn et al., 1998) to estimate the optimal corrections to the model surface velocities. However, effective data assimilation techniques of surface information rely on methods for projecting this information into the interior of the ocean. Unlike other coastal model domains that are

confined to the continental shelf and water depths less than 200m, the ICON model domain includes full-ocean depths exceeding 3000m. It is not expected that variability below the surface layer in the ICON model necessarily correlates with surface velocities. For this reason, we have explored the use of different vertical projection schemes that influence directly only the surface or surface mixed layer. These schemes for vertical projection of the PSAS-derived surface velocity corrections are based on a) energy conservation principles or b) application of Ekman theory.

Research on bioluminescence predictability has been performed in collaboration with Drs. D. McGillicuddy of WHOI; S.Haddock of MBARI; J.Paduan, L.Rosenfeld, S.Ramp of NPS; and P.Bissett of the Florida Environmental Institute. Dr. J. Kindle's group at NRL provided atmospheric products from COAMPS 9km predictions and outputs from the larger-scale Pacific West Coast model for the ICON model atmospheric and open boundary conditions.

Research on development of the fine-resolution Monterey Bay area model (ICON model) with CODAR surface currents data assimilation capability, and on development and evaluation of a fine resolution submodel (frsICON) nested inside and coupled to the ICON model, has been conducted in collaboration with Drs. J.D. Paduan, L.K. Rosenfeld, S.R. Ramp, C.A. Collins of NPS; Dr. J.K. Lewis of Scientific Solutions, Inc.; Dr. C.-R. Wu of USM; Drs. J.C. Kindle, P.A. Rochford of NRL; and S. Derado and S. Cayula of PSI.

WORK COMPLETED

We participated in the joint NOPP ICON, Autonomous Ocean Sampling Network (AOSN) and MOOS (MBARI Ocean Observing System) Upper-Water-Column Science Experiment (MUSE) sponsored by ONR.

The ICON and frsICON models have been run over the MUSE period (August - September 2000) with atmospheric forcing from the 9km resolution COAMPS model (wind and heat fluxes), and CODAR-derived surface currents were assimilated into the models.

The results from the model runs have been compared to the observations collected during the MUSE experiment and have been used for understanding these high-resolution observations.
Two cross-shore surveys of bioluminescence data conducted at two MUSE locations (north of the Bay and inside the Bay) at the 242nd and 245th calendar days were used in four numerical experiments designed to estimate the limits of bioluminescence predictions by tracers.

The ICON model outputs were used by Dr. McGillicuddy of WHOI for analysis of the oceanographic relationship between two cross-shore surveys of bioluminescence data by particle tracking techniques.

Schemes for assimilation of HF radar (CODAR) -derived surface currents have been implemented. The assimilation results are compared with *in situ* hydrographic data and limited subsurface mooring measurements.

RESULTS

The ICON and frsICON models' predictions show a good agreement with aerial SSTs observed during the MUSE period; observed mixed layer depths at MBARI M1 and M2 moorings, as well as with amplitudes and directions of currents at these moorings (see http://www.coam.usm.edu/ICON).

Bioluminescence potential predictability experiments show that assimilation of limited available BL observations into the tracer equations allow, with good accuracy, to reconstruct and predict (over a 72-hour period) the depth, distance offshore and intensity of the BL maximum.

The assimilation of BL data from only one cross-shore survey located inside of the Bay gave a good reconstruction of depth and distance offshore of the BL maximum observed during a cross-shore survey outside the Bay. However, the assimilation of only data from this outside cross-shore survey cannot reconstruct the observed bioluminescence structure inside the Bay.

These results tell us that, for successful use of the hydrodynamic model and tracer simulations for BL predictions, numerical tracer experiments similar to those described above should be conducted for the proposed locations and days of planned surveys before the final selection of actual days and locations. These numerical experiments will determine the influence of observed data on predictability at other locations and allow the determination of the optimal locations for the surveys.

Assimilation of CODAR surface velocity data in the region of the Monterey Bay has a positive impact on the model performance, as measured by independent moored velocity profiles. The comparison of magnitudes of complex cross-correlation coefficients between the model and M2 mooring currents are shown on Fig.1, where the blue curve is for the model run without assimilation, green curve is for the model run with assimilation of CODAR data only within the surface layer of the model (PSAS scheme), and red line is for the run with assimilation of CODAR data when PSAS-derived model surface currents corrections are vertically projected by using Ekman theory. The results show a clear impact of data assimilation down to depths of 120m, particularly for the case in which decaying corrections were made over the surface Ekman layer.

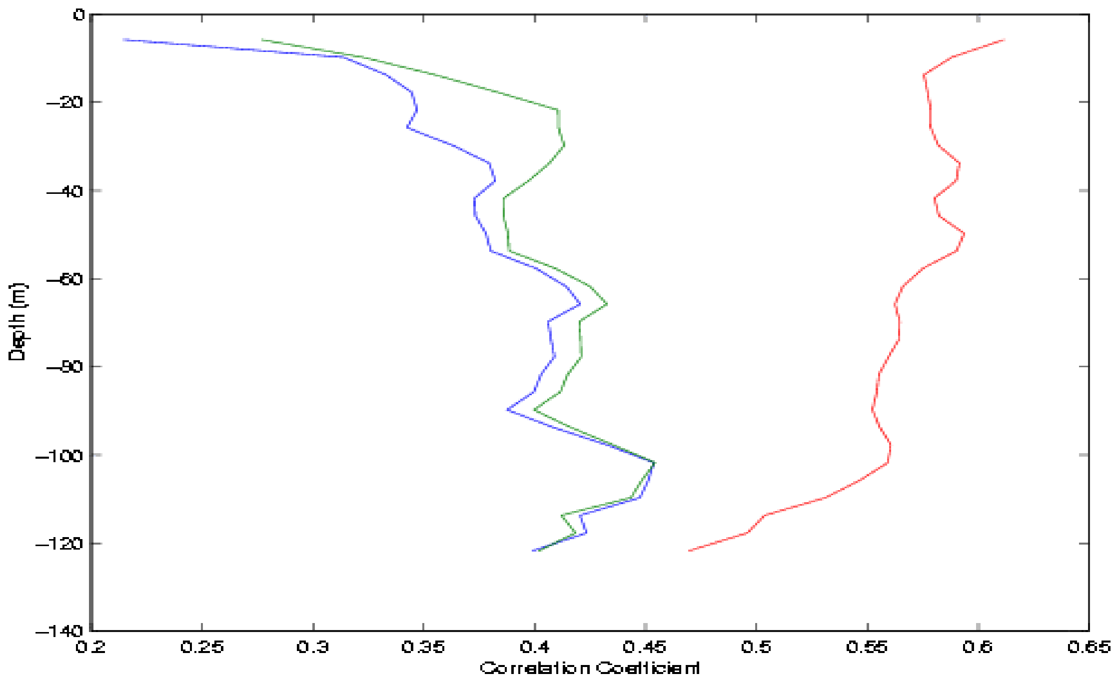

Figure 1. Magnitudes of complex cross-correlation coefficients for model versus observed currents at the M2 mooring. [The results show an increase in magnitude of complex cross-correlation between model and observed currents as we compare the model run without CODAR data assimilation, the model run with assimilation only within the model surface layer, and that with assimilation over the Ekman layer.]

IMPACT/APPLICATIONS

In a situation when it is difficult to obtain extensive data sets to validate numerical models and techniques in many areas of strategic importance, our development and testing of coupling and data assimilation techniques, together with extensive observational programs in and around the Monterey Bay Area, allow continued development of techniques for data assimilation, atmospheric forcing, and coupling between models.

TRANSITIONS

Circulation fields from the ICON and frsICON models have been used in predictions of the bioluminescence potential and for understanding high-resolution observations within the framework of a joint effort by ICON, Autonomous Ocean Sampling Network (AOSN) and MOOS (MBARI Ocean Observing System) Upper-Water-Column Science Experiment (MUSE).

RELATED PROJECTS

"An Innovative Coastal-Ocean Observing Network (ICON)" (NOPP), "Autonomous Ocean Sampling Network (AOSN)" (NOMP, ONR) and MBARI "Upper-Water-Column Science Experiment (MUSE)". Modeling is conducted in coordination with a joint effort of the ICON/AOSN/MUSE projects.

NRL "Coupled Biophysical-dynamics Across the Littoral Transition (CoBALT)". CoBALT PWC predictions and COAMPS products are used for open boundary and surface forcing in the Monterey Bay area models (ICON and frsICON models).

Collaboration with Dr. Kirwan's group from Univ. of Delaware on application of Normal Mode Analysis in data assimilation.

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